

Why Research on Gas Interchangeability is Needed

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CEC Stakeholders Group

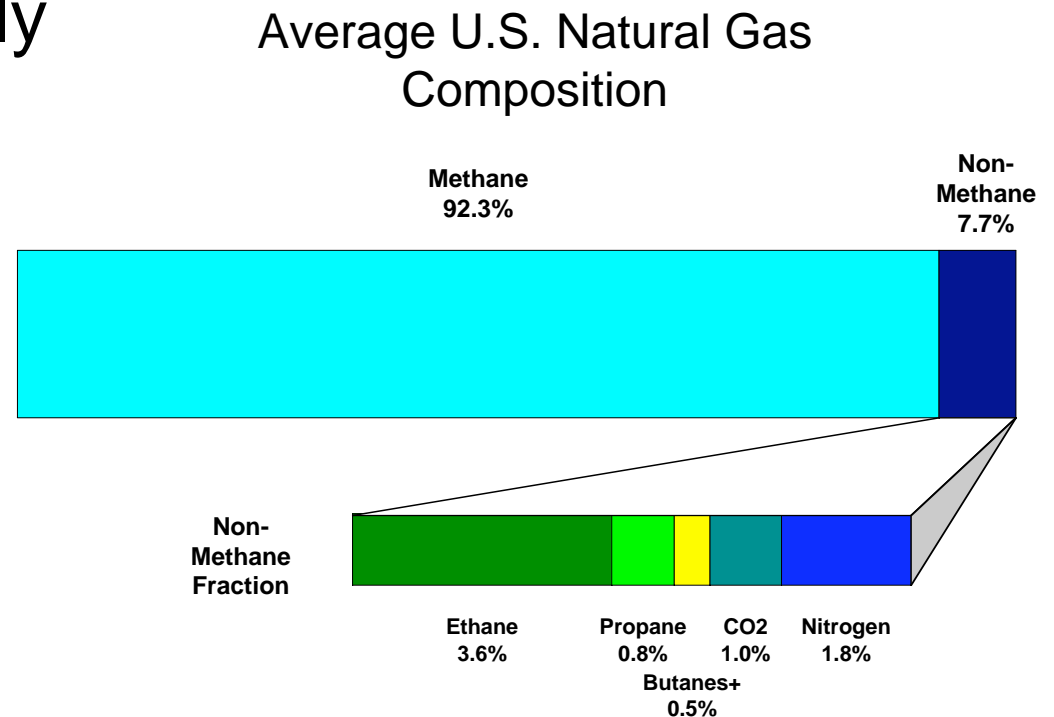
Sacramento, CA

October 29, 2007



Typical Natural Gas Composition

- Natural gas is mainly methane
 - About 90-95% by volume on average
- Balance:
 - Non-methane hydrocarbons (e.g., ethane, propane)
 - Other gases (e.g., carbon dioxide, nitrogen)

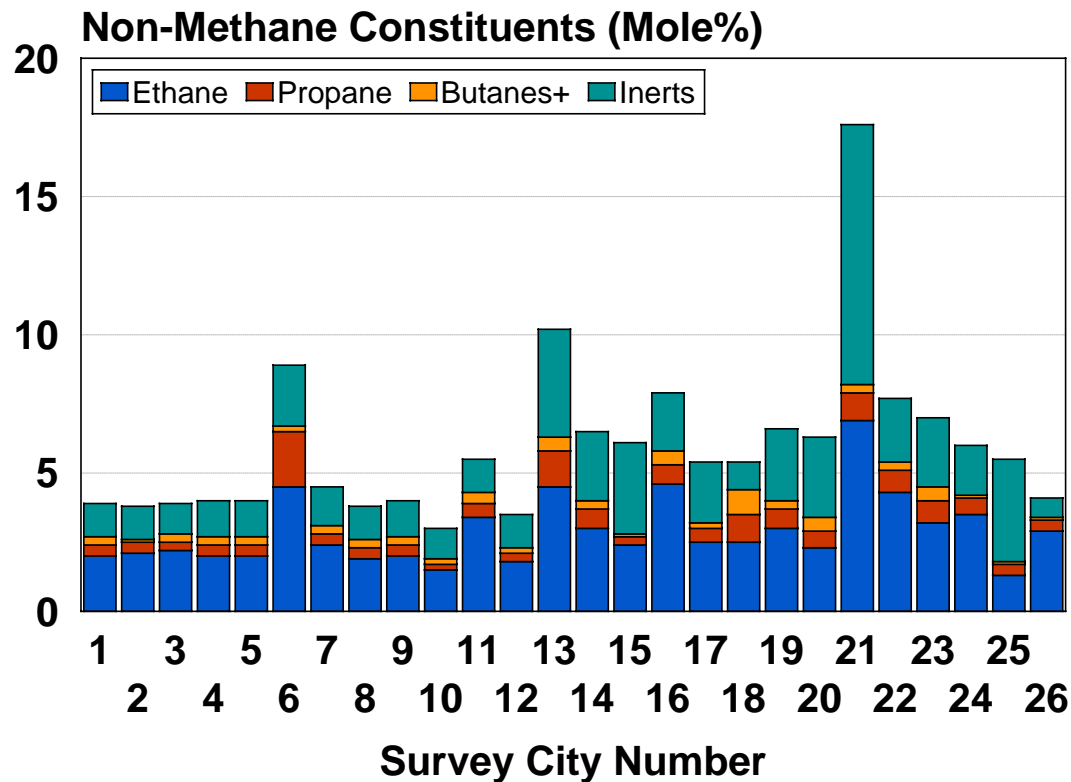


Source: Gas Technology Institute

Regional Natural Gas Composition Variations Exist

Average Natural Gas Composition -- Twenty Six US Cities

Non-Methane Natural Gas Constituents



Source: Gas Technology Institute

Natural Gas – Gas Quality

- Domestic natural gas is a hydrocarbon mixture, predominantly methane, with some nitrogen, carbon dioxide, and other species, and a higher heating value commonly between 1000 and 1050 Btu/scf
- LNG economics lead to a similar fuel gas with different ranges of hydrocarbons larger than methane and higher heating values between 1025 and 1200 Btu/scf
- Gas quality from other sources (unconventional, landfills, gasification, etc.) can vary even more than LNG

Interchangeability is Defined As -

The ability to substitute one gaseous fuel for another in a combustion application without materially changing operational safety or performance and without materially increasing air pollutant emissions

Source – NGC+ Working Group on Interchangeability White Paper
presented to FERC, Feb. 2005

Gas Quality Guidelines

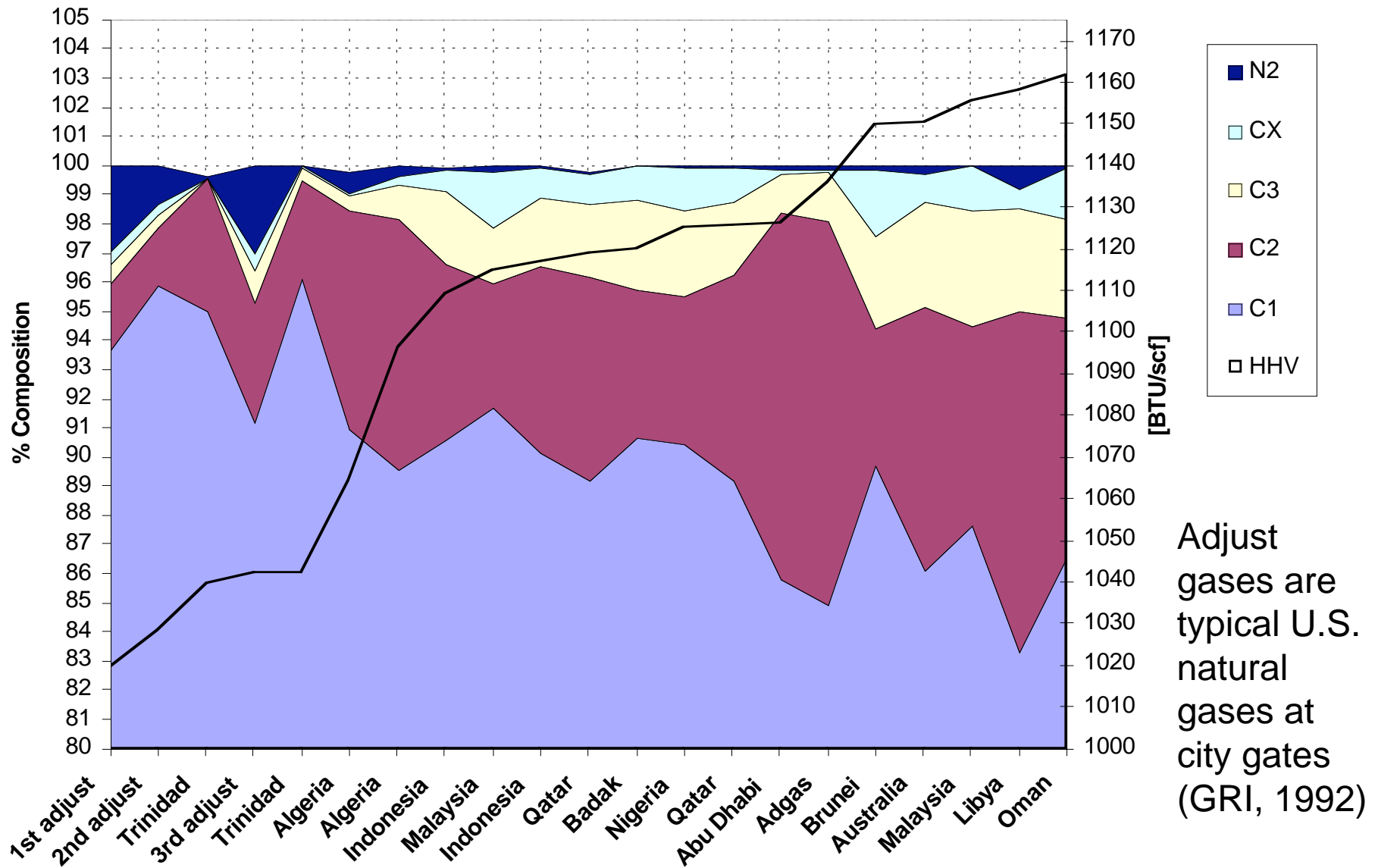
- Regulators assure merchandisable gas by specifying gas quality ranges
 - Common world practice is to set Wobbe Index limits for LNG
 - Domestic regulations often set gross heating value and composition limits
- Combustion processes and regulations vary widely between appliances, industrial burners, and turbine systems
- Composition swing and quality changes may be acceptable for performance but still may lead to changes in emissions and flame characteristics

Wobbe Number

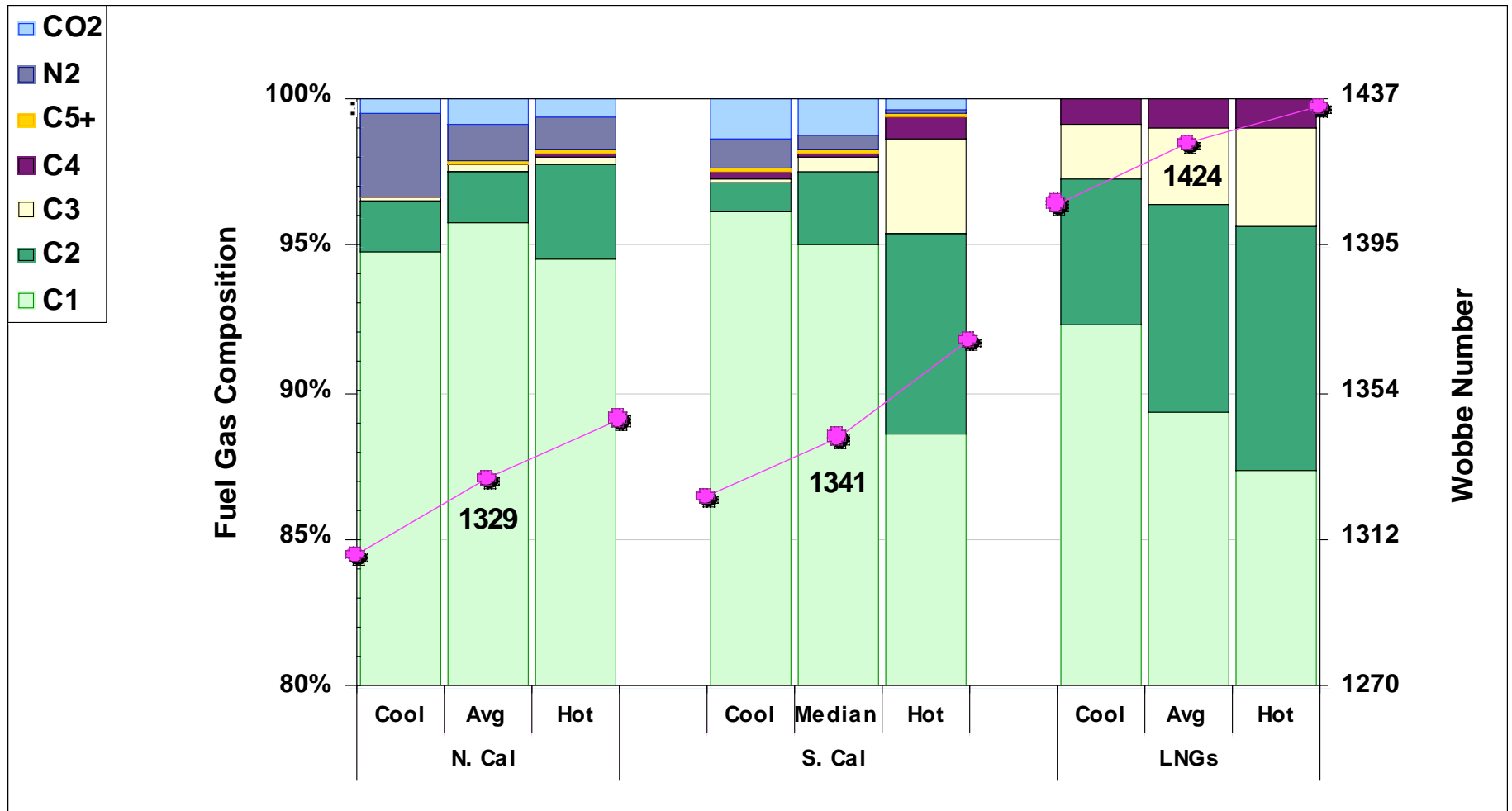
- Generally accepted as the best SINGLE index to determine interchangeability
- For natural gas – alkanes – heat input through an orifice (Btu/h) at constant pressure is
 - proportional to heating value and
 - inversely proportional to the square root of specific gravity
- Wobbe Number does not fully address interchangeability because changes in flame characteristics are not addressed

$$W = HHV / (\text{sp. gr.})^{0.5}$$

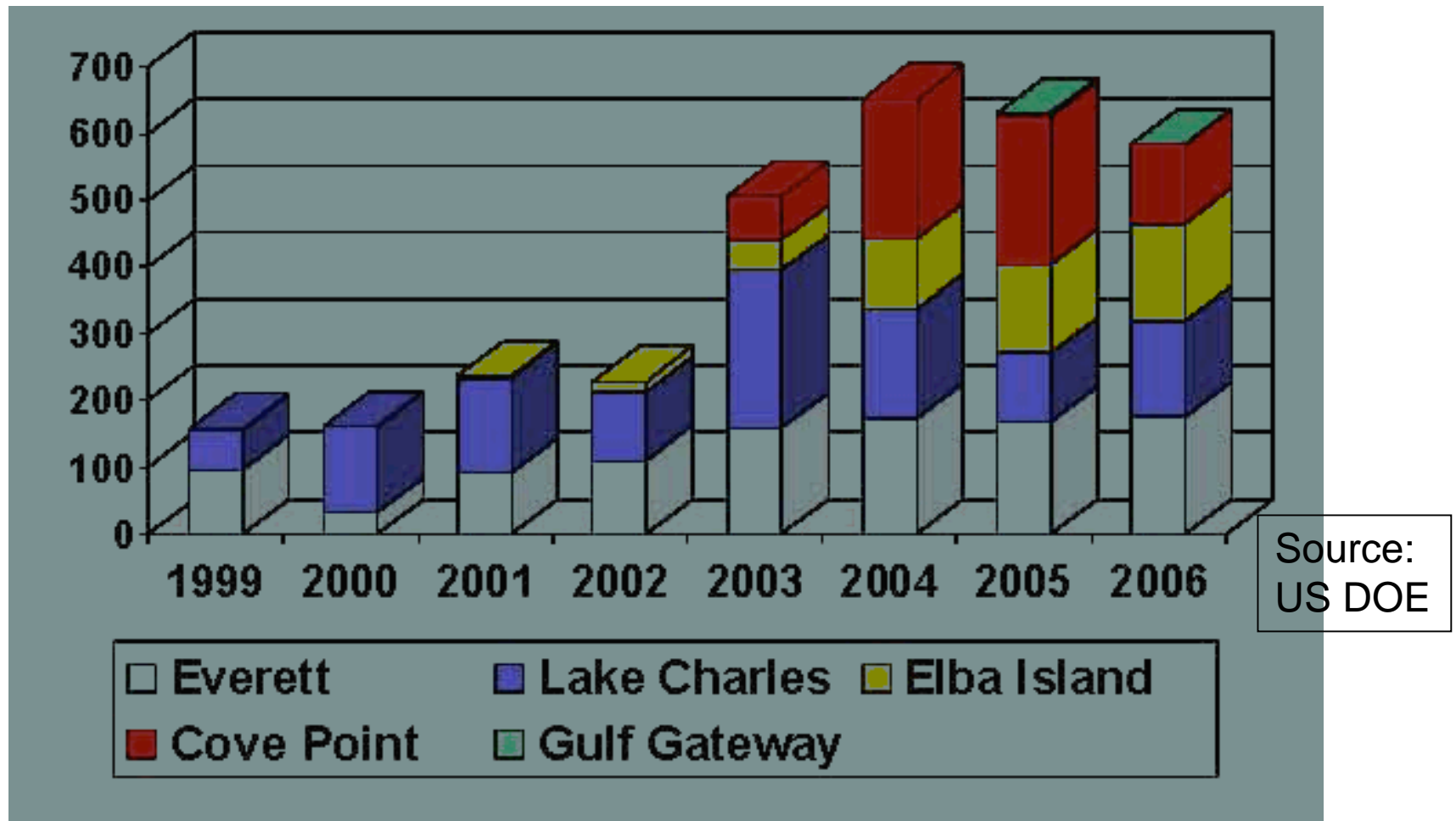
Natural Gas and LNG



Natural Gas Variability in California

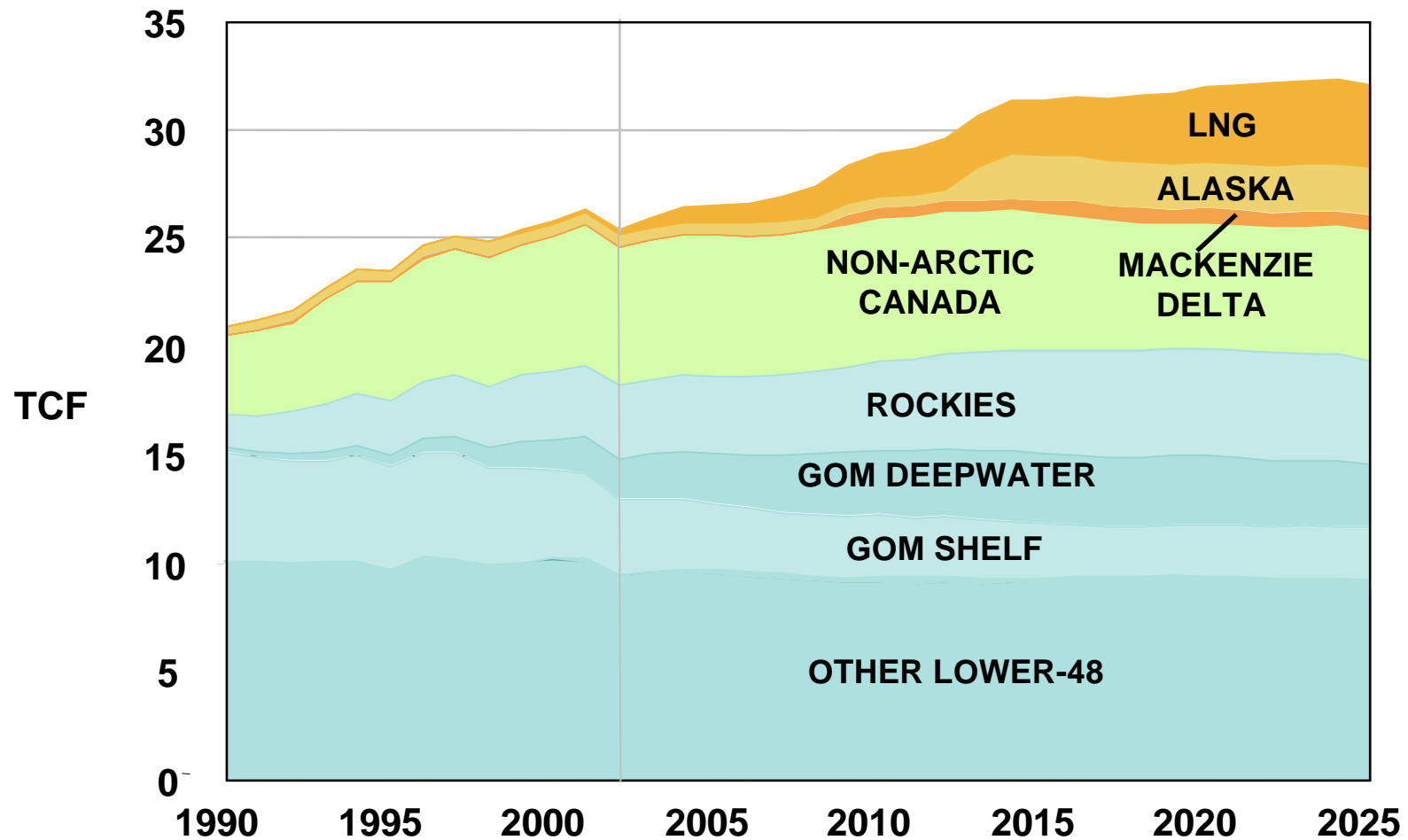


LNG Imports Are Increasing



- Trinidad is largest source of imported LNG
- 2006 Sources: Trinidad 389, Algeria 17, Egypt 120, Nigeria 57

Future Supplies From Traditional and New Resources



Source: National Petroleum Council (2003)

Interchangeability is Important Now

- U.S. gas compositions have been stable for decades
- This is changing as the U.S. begins importing more gas
- Combustion systems have been designed and tuned for this stable natural gas in regions of the country
- LNG and unconventional gas use is expanding the range of gas compositions
- Combustion systems can operate poorly and produce more emissions when gas composition changes too much or too fast
- Changing combustion systems or modifying LNG to narrow composition ranges is costly
- Suppliers, manufacturers, pipelines, gas companies need guidelines to use LNG safely and manage costs

Interchangeability Misconceptions Must be Addressed

The Los Angeles Times

**Natural Gas From Overseas Sources Is
Raising Concerns; Critics say imported
LNG burns hotter and pollutes more
than the domestic product.**

Elizabeth Douglass

21 September 2006

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State utility regulators are embroiled in a debate over new kinds of natural gas that opponents contend would worsen air pollution, trip up power plants and make gas stoves, water heaters and other equipment more prone to fires.

The dispute concerns foreign liquefied natural gas, which could begin flowing into local pipelines within two years. The gas from other continents is chemically different and burns hotter than most U.S. natural gas.

Present Tariffs Are Inadequate

- Most tariffs specify maximum heating value and maximum inerts (such as CO₂ and nitrogen)
- These indices are inadequate to assess acceptable interchangeability
- Most commonly proposed approach is to use –
 - Wobbe number range to keep combustion performance in desired ranges
 - One or more indices to address secondary issues of emissions and performance
- No national consensus yet for preferred approach to interchangeability indices or desirable ranges

Possible Combustion Problems With High BTU Gas

Reported Problem	From
Flame lifting	Excess air
Backfiring	low velocity
High CO	Incomplete combustion
High NO _x	Higher flame temperature
Yellow tipping	Flame lengthening from incomplete combustion
Sooting	Unburned hydrocarbon buildup

Approaches to Interchangeability Prediction

- Single index (Wobbe, modified Wobbe, etc.)
 - Incapable of describing all possible situations
- Multiple indices (AGA, Weaver, etc.)
 - Specific to burner type
 - Do not account for all fuel gases or emissions
 - Most common U.S. approach
- Diagrams
 - Do not account for all fuel gases or emissions
 - Attempt to combine Wobbe index with composition parameters
 - Many variations and not universally accepted
 - Often used in Europe

Early Interchangeability Studies (pre-1980)

- Long history of addressing “interchangeability” of gaseous fuels
- Covers a wide spectrum of fuels
- Common practice in U.S. relies on Wobbe Index and AGA Indices

Author	Year	Country	Technique
Wobbe	1926	--	Single Index
AGA	1933	U.S.	Single Index
Willien	1938	U.S.	Single Index
Knoy	1941	U.S.	Single Index
AGA (Bulletin 36)	1946	U.S.	Multiple indices
Weaver (USBM)	1951	U.S.	Multiple indices
Delbourg	1953	France	Diagram
Gilbert and Prigg	1956	U.K.	Diagram
Grumer, Harris, Rowe	1956	U.S.	Diagram
Holmqvist	1957	Sweden	Diagram
Shuster	1957	Germany	Single Index
Harris and Lovelace	1968	U.K.	Diagram
Van der Linden	1970	Holland	Diagram
Soomers and Jost	1973	Germany	Single Index
Harris and Wilson	1974	U.K.	Diagram
France	1976	U.K.	Diagram
Dutton	1978	U.K.	Tetrahedron

Interchangeability Projects (partial)

- AGA, Bulletin 36, 1952, later reports, appliances, limit curves, indices
- USBM, Weaver, 1951
- Internal studies –
 - SoCalGas, multiple combustion systems
 - Florida Gas Transmission, appliances
- Washington Gas and Light, appliances for WGL territory, TIAX, 2003
- **GTI, Gas Interchangeability Tests, GRI-03/0170, 2003**
- California Energy Commission PIER, catalytic combustion
- DOE NETL paper, 2000, power systems, turbines
- World Gas Conf., 2003, wide Wobbe range, 21st century appliance
- ILEX Consulting, U.K., 2003, impact of fuel gas changes in U.K.
- European study of burner control system performance, 2000
- Gaz de France, current work on French concerns
- Gas Unie, recent work related to fuel changes and H₂ use
- SoCalGas study, current White Paper, multiple combustion systems
- **CEC study (2006) - GTI (industrial combustion systems), LBNL (appliance air quality)**
- GAMA – New appliance performance measurements, May 2007

Effects of Fuel Changes:

Appliances and Industrial Burners

- Different appliance burners show changes in performance
- No burner exhibited a failure case of flame lifting, excessive yellow tipping, or high CO emissions
- Important performance characteristics are different for industrial burners than for residential appliances
- Industrial burners are monitored more closely but operated at more demanding conditions

Effects of Fuel Changes:

Appliances and Industrial Burners

- Industrial burners can be categorized
 - Some burner types, like appliances, are relatively unaffected by changing fuel
- Burners sensitive to changing fuel include:
 - Burners for which flame temperature changes strongly impact the process
 - Burners in high temperature processes or where emissions are tightly regulated
 - Burners operating close to stability limits
- Only sensitive burner types need to be evaluated for gas interchangeability

Industrial Burners – *Interchangeability Concerns*

- Unlike appliances, industrial burners are complex, highly engineered, and operate under precisely controlled conditions
- Changing fuel can affect industrial burners
 - Operations
 - Flame length, temperature, flame shape, mixing patterns, etc.
 - Safety
 - Stability, operating range, air/fuel ratio, etc.
 - Meeting regulations
 - Emissions of NO_x, CO, etc.
- Wobbe is still best index of interchangeability

The NGC+ Working Group

- FERC requested a White Paper on interchangeability to address concerns related to introduction of LNG
- An NGC+ working group, an open group led by Ted Williams of AGA, spent a year preparing a White Paper
- White Paper was presented to FERC in Feb. 2005
- White Paper discusses fuel gas interchangeability and defines interim guidelines for interchangeability
 - region's historic Wobbe value $\pm 4\%$
 - Maximum Wobbe 1400
 - Maximum heating value 1110 Btu/scf
 - Maximum C₄+ 1.5%
 - Wobbe and HHV limits can be exceeded with historical evidence
- White paper provides a 'gap analysis' of needed research

Involved in The NGC+ Process

- Concerned groups included
 - LNG producers
 - Pipeline operators
 - Gas companies (LDCs)
 - Turbine manufacturers and operators
 - Appliance and burner manufacturers
- Other groups involved in the NGC+ working group –
 - Gas Technology Institute
 - Edison Electric Institute
 - AGA
 - INGAA
- Only an approach inclusive of all stakeholders nationally and regionally will be accepted to meet technical, business, and FERC requirements for interchangeability indices and ranges

What Needs to be Learned?

Application	Concern	Status	Need
Appliances	Millions of unregulated units	Studies made, results must be compared	Testing of old, maladjusted, and new units
Commercial/Industrial Burners	Widest range of use, efficiency, emissions	Not yet addressed	Extensive testing
Engines and Boilers	Knock, efficiency, emissions, stable combustion	Mobile engines studied, others not yet addressed	Review mobile engine data and testing
Turbines/Microturbines	Efficiency, emissions, turbine life	New FL study planned with full-scale turbines	Collect turbine maker data and testing
Non-combustion Uses	Added process cost, plant modification	Not yet addressed	Market analysis and data collection

On-Going Efforts to Fill the Gaps

- Appliances
 - Many studies conducted but gaps remain
 - California Energy Commission funding comprehensive literature review and air quality studies by LBNL
 - Focused studies by GAMA, Xcel, others
- Industrial / commercial burners
 - CA Energy Commission funding first-ever study by GTI
- Engines
 - Engine makers improving models – only older engines are a significant concern
- Turbines / microturbines
 - Studies on-going by turbine manufacturers
 - Recent study in FL and on-going studies at DOE NETL

International Natural Gas Situation

- For Higher Heating Value), international natural gas networks consist of three major groups
 - U.K. and U.S.: distributed gas is lean, with a HHV usually less than 42 MJ/m³ (1065 Btu/scf)
 - Asia (Japan, Korea, Taiwan): distributed gas is rich, with a GCV greater than 43 MJ/m³ (1090 Btu/scf)
 - Continental Europe: acceptable GCV range is quite wide—about 39-46 MJ/m³ (990-1160 Btu/scf)